WATER, ENERGY, AND BIOGEOCHEMICAL BUDGETS TEAM

Mission

As part of the national WEBB program, the goal of the Northern Temperature Lakes (NTL) project is to improve understanding of processes controlling water, energy, and biogeochemical budgets and to provide information from which to better predict water, energy, and biogeochemical fluxes over spatial and temporal scales. The findings of the studies will improve the capability to assess effects of climate variations (for example, precipitation, temperature, and radiative fluxes) and human activities (for example, land-use changes, ground-water withdrawal, and chemical contamination) on hydrological, biological, and chemical systems in the northern temperate watersheds.

Team Members

John F. Walker, Research Hydrologist/Engineering
David P. Krabbenhoft, Research Hydrologist/Geochemistry
Randy J. Hunt, Research Hydrologist/Geology
Paulette R. Homant, Hydrologic Technician

PROJECTS

The landscape in the northern highlands lake district is dominated by a mosaic of lakes interconnected by ground water.

Using portable drill rigs allows the installation of monitoring wells in remote locations.

HYDROLOGIC AND BIOGEOCHEMICAL BUDGETS IN TEMPERATE LAKES AND THEIR WATERSHEDS, NORTHERN WISCONSIN

COOPERATOR:

Global Change Hydrology Program, U.S. Geological Survey

PROJECT CHIEFS:

John F. Walker
David P. Krabbenhoft
Randy J. Hunt

LOCATION:

North-Central Wisconsin

PROJECT NUMBER:

WI 17500

PERIOD OF PROJECT:

October 1990–Continuing

PROBLEM

There has been expanding evidence that rates of global change are increasing. There is a need for research to identify, describe, and quantify the processes that control the Water, Energy, and Biogeochemical Budgets (WEBB) of aquatic ecosystems in order to understand and predict their responses to global change. Promotion of such research is the function of the Water Resources Discipline's WEBB program. In the northern highlands lakes district of north-central Wisconsin, five lakes and two bog lakes have been the site of long-term ecological research conducted by University of Wisconsin scientists for the past decade. These studies have provided extensive information about biological and chemical features of the lake systems, but understanding of interactions among the lakes, streams, ground-water system, and wetlands is still limited. Research is urgently needed to describe these interactions and basin-wide processes that influence the character of the lakes.

OBJECTIVE

Objectives are to: (1) describe processes controlling water and solute fluxes in northern Wisconsin lake watersheds, (2) examine interactions among those processes and their relations to climatic variables, and (3) improve the capability to predict changes in water and solute fluxes for a range of spatial and temporal scales. Fulfillment of these objectives in Wisconsin will contribute to meeting the overall objective of the federal global change program—to understand processes underlying the responses of hydrologic, biologic, and chemical systems to climate variations and human activities.

APPROACH

Selected streamflow/recharge sites on tributaries of Trout Lake are the sites for detailed research of hydrologic processes. Most of the current research effort is

concentrated at Allequash Creek, one of four inflowing tributaries of Trout Lake. Analyses of hydrologic connections among precipitation, stream flow, and ground water are conducted at three cross sections of the Allequash Creek basin. Monitoring and sampling equipment installed at these sites include piezometer nests, lysimeters, tensiometers, precipitation collectors, and thermocouple nests. Analyses of stable isotopes (^{13}C, ^{18}O, ^{87}Sr, and ^{2}H) are also used to determine water exchange pathways and sources of stream water. The site-specific hydrologic research is supported by data from several rain gages throughout the study area and a complete climatological station in the vicinity.

Stream- and ground-water samples, collected at each of the Trout Lake tributaries and at different points in the Allequash system, undergo analysis for nitrogen species, phosphorus, silica, organic carbon, major ions, and metals. Tributary sampling is done on a monthly basis, supplemented with more intense sampling of particular storms. Coupled with hydrologic data, the water sampling provides a basis for describing chemical budgets.

Investigation of geochemical processes that control transport of important chemical species across stream and lake sediments involves fine-scale sampling at the sediment/water interface. This is done by a variety of techniques, including membrane equilibrators, core squeezing, microprobes, and seepage meters.

PROGRESS (July 2001 to June 2002)

Ongoing data collection efforts have continued, which include collecting samples at the streams tributary to Trout Lake, operating 5 continuous-record stream gages, monitoring water levels in a network of 22 wells, and collecting samples from 36 zero-tension and 31 suction lysimeters. Four detailed monitoring sites were established and operated at existing benthic invertebrate sampling sites to support that effort. Drafts of 6 papers were completed and are in press or review. Work continued on four new research efforts, including a comparison of solute budgets across the five WEBB sites, a unified approach to watershed modeling applied to the five WEBB sites, comparison of land-use history and sediment and carbon budgets across the five sites, and an investigation of macroinvertebrate populations and energy dynamics in the Allequash Creek system.

PLANS (July 2002 to June 2003)

Basic data collection efforts will continue, as well as data collection efforts related to flow path studies, carbon dynamics in the hyporheic zone, unsaturated zone processes, and macroinvertebrate dynamics. A variety of papers currently in preparation will be published (see list of publications).

REPORTS

Pint, C.D., Hunt, R.J., and Anderson, M.P., in review, Calibrating a watershed model of a ground water dominated stream system: Allequash Creek Basin, northern Wisconsin: submitted to special watershed issue of Ground Water.

Hunt, R.J., in review, Evaluating the importance of data type and location using parameter estimation and groundwater flow models: submitted to Ground Water.

Hunt, R.J., Haitjema, H.M., Krohelski, J.T., and Feinstein, D.T., in review, Simulating lake-ground water interactions with models: MODFLOW and analytic element approaches. Director approved; invited paper for special MODFLOW 2001 issue of Ground Water.

Walker, J.F., Hunt, R.J., Bullen, T.D., Kendall, C., Krabbenhoft, D.P., and Elder, J.F., in review, Spatial and temporal variability of isotope and major ion chemistry in the Allequash Creek basin, northern Wisconsin: submitted to special watershed issue of Ground Water.

Walker, J.F., Hunt, R.J., Saad, D.A., and Plummer, L.N., in review, Using CFCs to age date ground-water recharge from lakes: submitted to Limnology and Oceanography.

Hunt, R.J., 2002, Evaluating the importance of future data collection sites using parameter estimation and analytic element groundwater flow models *in* Proceedings of the XIV International Conference on Computational Methods in Water Resource: Delft, Netherlands, Delft University.

Hunt, R.J., Haitjema, H.M., Krohelski, J.T., and Feinstein, D.T., 2001, Simulating groundwater-lake interactions with models: MODFLOW and analytic element approaches, p. 328-334 in MODFLOW 2001 and Other Modeling Odysseys *in* Proceedings of the 4th International Conference of the International Ground Water Modeling Center, Golden, CO: Colorado School of Mines.

Elder, J.F., Goddard, G.L., and Homant, P.R., Phosphorus retention and yields in hydrologically different types of wetland systems in Wisconsin (USA), in Proceedings of Societas Internationalis Limnologiae, Dublin, Ireland (in press).

Elder, J.F., Rybicki, N.B., Carter, V., and Weintraub, V., 2000, Sources and yields of dissolved carbon in Northern Wisconsin stream catchments with differing amounts of peatland: WETLANDS, v. 20, no. 1, p. 113–125.

Walker, J.F. and Bullen, T.D., 1999, Trout Lake, Wisconsin: A water, energy and biogeochemical budgets program site, U.S. Geological Survey Fact Sheet 134–99, 4 p.

Hunt, R.J., Anderson, M.P., and Kelson, V.A., 1998, Improving a complex finite-difference ground water flow model through the use of an analytic element screening model: Ground Water, v. 36, no. 6, p. 1011–1017.

Elder, John F., Carter, Virginia, and Rybicki, N.B., 1998, Dissolved carbon mobilization in peatland/stream systems in northern Wisconsin (U.S.A.), Proceedings of V INTECOL Wetlands Symposium, Perth, Australia (in press).

Champion, G., 1998, Transient and steady-state flow of models of ground-water and lake system: Trout Lake basin, northern Wisconsin: Madison, Wis., University of Wisconsin, MS, 109 p.

Hunt, R.J., Kelson, V.A., and Anderson, M.P., 1998, Linking an analytic element code to MODFLOW–Implementation and benefits, in MODFLOW 98: Proceedings of the 3rd International Conference of the International Groundwater Modeling Center, Golden, Colorado, Colorado School of Mines, p. 497–504.

Keating, E.H., and Bahr, J.M., 1998, Using reactive solutes to constrain groundwater flow models at a site in northern Wisconsin: Water Resources Research, v. 34, no. 12, p. 3561–3571.

Keating, E.H., and Bahr, J.M., 1998, Reactive transport modeling of redox geochemistry: Approaches to chemical disequilibrium and reaction rate estimation at a site in northern Wisconsin: Water Resources Research, v. 34, no. 12, p. 3573–3584.

Schindler, J.E., and Krabbenhoft, D.P., 1998, The hyporheic zone as a source of dissolved organic carbon and carbon gases to a temperate forested stream: Biogeochemistry, v. 43, p. 157–174.

Walker, J.F., and Krabbenhoft, D.P., 1998, Groundwater and surface-water interactions in riparian and lake-dominated systems, in McDonnell, J.J., and Kendall, C., eds., Isotope tracers in catchment hydrology: Amsterdam, The Netherlands, Elsevier, p. 467–488.

Bullen, Thomas D., Krabbenhoft, D.P., and Kendall, Carol, 1996, Kinetic and mineralogic controls on the evolution of groundwater chemistry and $87_{Sr}/86_{Sr}$ in a sandy silicate aquifer, northern Wisconsin, U.S.A., Geochimica et Cosmochimica Acta, v. 60, no. 10, p. 1807–1821.

Krabbenhoft, D.P., Benoit, J.M., Babiarz, D.L., Hurley, J.P., and Andren, A.W., 1995, Mercury cycling in the Allequash Creek Watershed, northern Wisconsin, Water, Air, and Soil Pollution, v. 80, p. 425–433.

Keating, E.H., 1995, Reactive transport modelling: an application to redox geochemistry of groundwater discharging to a stream in northern Wisconsin, Ph.D. thesis, University of Wisconsin-Madison: Madison, Wisconsin, 216 p.

Krabbenhoft, D.P., Bowser, Carl J. Kendall, C., and Gat, J.R., 1994, Use of oxygen-18 and deuterium to assess the hydrology of groundwater-lake systems, in Environmental Chemistry of Lakes and Reservoirs (L.A. Baker, editor), American Chemical Society, p. 67–90.

Elder, J.F., Krabbenhoft, D.P., and Walker, J.F., 1992, Water, Energy, and Biogeochemical Budgets (WEBB) program: data availability and research at the Northern Temperate Lakes site, Wisconsin: U.S. Geological Survey Open-File Report 92–48, 15 p.